INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

DESIGN FOR RECYCLING IMPROVING ENVIRONMENTAL PERFORMANCE OF AUTOMOTIVE INDUSTRY IN BRAZIL.

Heloisa V. de Medina[1], Ricardo M. Naveiro[2], Ana Julieta Malafaia[2]

1 Senior Researcher at CETEM Center for Mineral Technology
2 Professor at Federal University of Rio de Janeiro, MSc. Student at Federal University of Rio de Janeiro in Production Engineering

ABSTRACT:

This paper discusses how car companies in Brazil can get better advantage of eco-designing practices fostering car components recycling and improving their environmental performance. Industrial production best practices have been enforced worldwide by environmental regulations and eco-design recommendations for materials selection and recycling. Since the last ten years designing activity has been enlarged to cope with environmental innovation requirements. Design for Environment –DFE- and Design for Recycling -DFR- methods were developed. Firstly, this article shows how vehicles eco-design has been fostered in Europe and how automakers and suppliers have gradually incorporated environmental criteria as recyclability into new vehicles design. Secondly, it presents eco-design concepts and practices associated to eco-design tools highlighting the gap between the recyclability -materials technical ability to be recycled- and recycling –economic activity for materials recovery and reuse-. It also points out that these practices have continuously shorted new vehicles models lifetime, diversifying and speeding the launching of new models. This trend is generating a great volume of end of series components (ESC), which are difficult and costly to be managed at the local plants in Brazil as indicates an ongoing case study at Rio de Janeiro State. And thirdly, it analyses the Brazilian present situation concerning eco-design and recycling providing some examples. Based on these evidences the authors came to the conclusion that Brazilian car industry has nowadays a better environmental performance as result of eco-design practices but there is still a gap of economical effectiveness to be overcome.

Keywords: design for recycling; automotive industry; end of series components.

1. INTRODUCTION

A global life cycle approach has been adopted since the Directive 2000/53/EC - the ELV – End of Life Vehicles- was officially approved by the European Parliament and Council in September 2000. The Directive states: "The requirements for dismantling, reuse and recycling of end-of-life vehicles and their components should be integrated in the design and production of new vehicles. And furthermore producers should ensure that vehicles are designed and manufactured in such a way as to allow the quantified targets for reuse, recycling and recovery to be achieved."[1] The main target is to get 95% recyclable vehicles up to 2015. That means that from now on European car companies are expected to put recyclability first, among other design environmental criteria.

In this scenario since the year 2000 new enters European automotive manufactures in Brazil are following the same environmental criteria adopted at their origin countries. The new vehicles, even though they were conceived aboard, have the same material composition and characteristics, with few adaptations to local conditions. Besides automotive production in Brazil was traditionally settled as a complete domestic integrated chain, and the first ones are 60's years old. So the majority of parts and components are domestically produced at the same international standards assuring technical and environmental qualities, since around 40% of the total production is exported. Additionally some few new generation components are still imported. And in this case they are surely made toxic-substances free, recyclable or renewable materials.

In short vehicles that are being produced by multinationals European companies in Brazil, mainly the newcomers, up to 15 new groups since the early nineties, are encompassing the European Directive recommendations concerning eco-design and recyclability. Nevertheless, the eco-design practices do not yet consider the manual dismantling requirements and the materials separation of post shredder parts. Besides Brazil's industrial and technological infrastructure has not been prepared to face this situation. So it can be seen as an opportunity as well as a threat. An opportunity if we are able to take advantage of this promoting recycling activities and a recycled automotive materials market as well. A threat if we are not able to establish the adequate public policies for industrial and technological development to enforce clean processes uses to dismantling and recycling car materials according to international quality standards. At the present moment we are between these two scenarios risking getting into the second one that would be a great loss in both sense economic and environmental aspects. For instances there are some car companies that are destroying great volume of end of series components (ESC) delivering them to recyclers without any previous materials selection or disassembly as required for recycling purposes. In this sense there is a paradoxes having state of art vehicles and components eco-designed to be easily disassembled, and made of recyclable materials, been spoiled for economic reasons. According to the car companies these reasons are linked to Brazilian tributary system among other aspects.

Some initial results from the presented ongoing case study allow us to state that the tributary aspects as well as the Brazilian environmental legislation and practices on eco-design and recycling are important to evaluate the viability an alternative ESC management system that could take better advantage of these eco-designed products. This new system should include a disassembly and separation phases organization on economic and technical basis, to assure the sustainable performance of the whole process, to make possible a high quality recycling of ESC providing the secondary materials recovered to be reused on new vehicles. Up to now our case study had provided the technical and economic data on ESC management and destruction. At the final phase it will get a sample of ESC done for disassembling and sorting, in order to determine how to get the best advantages from the eco-design parts for recycling them.

2. EUROPEAN LEGISLATION ON VEHICLES RECYCLING AND ECO-DESIGN

In October 2000, the Directive 2000/53/EC on ELV Recycling was published and since then it has been gradually implemented and supported by other secondary legislation –eleven up to 2006- related on ELV including Environmental Commission Decisions, European Council Decisions and a Commission Proposal for a Directive of the European Parliament and the Council on the type-approval of motor vehicles with regard to their re-usability, recyclability and recoverability amending Council Directive 70/156/EEC. Other five of them are on Annex II amending. There is also secondary legislation at national level and the European Commission services have developed a "Guide" on the legislative acquits which, aims at facilitating the implementation of the Directive and the secondary legislation at both level.

The 2000/53/EC ELV Directive aims at making vehicle dismantling and recycling more environmentally friendly, sets clear quantified targets for reuse, recycling and recovery of vehicles and their components and pushes producers to manufacture new vehicles also with a view to their recyclability. Concerning recyclability rates the ELV Directive [1] require that: *Members States shall take the necessary measures to ensure that the following targets are attained by economic operators:*

a) no latter than 1st January 2006, for all end-of life vehicles, the reuse and recovery shall be increased to a minimum of 85% by an average weight per vehicle and year. Within the same time limit the reuse and recycling shall be increases to a minimum of 80 % by an average weight per vehicle and year;

b) no latter than 1st January 2015, for all end-of-life, vehicles the reuse and recovery shall be increased to a minimum of 95% by an average weight per vehicle and year. Within the same time limit the reuse and recycling shall be increases to a minimum of 85 % by an average weight per vehicle and year;

Concerning eco-design proposes the Directive [1] says that the requirements for dismantling, reuse and recycling of end-of-life vehicles and their components should be integrated in the design and production of new vehicles. And that: *producers should ensure that vehicles are designed and manufactured in such a way as to allow the quantified targets for reuse, recycling and recovery to be achieved.* The Directive also states that economic aspects of recycling have to be taken into account in order to promote a market for recycled materials *(...) The development of markets for recycled materials should be encouraged.* And for this purpose Member States are required to enforce the provisions of the Directive mainly regarding the access of small and medium sized enterprises to collection, dismantling, treatment and recycling market. Nevertheless, carmakers are supposed *to provide authorized treatment facilities with all requisite dismantling information, in particular for hazardous materials.*

Although to reach the Directive recyclability rate target of 95% by 2015 is a great challenge for designers and engineers to get vehicles free from toxic substances is the core problem to get them recycled. Since the ELV are up to now worldwide recycled by a maximum rate of 75% the most important efforts are being put into reducing the remaining 25% - mostly made of plastic materials-. A number of actions have been taken by European national government in setting the basis of a ELP -end of life products- recycling sector at research and industrial level as well. In cooperation with the automotive companies and materials producers they are enforcing and promoting recycling initiatives. Technically speaking recycling means the reintroduction of waste material – scrap from industrial transformation - or recovered materials –from end of life products- into the production cycle to replace, in part or in total, a virgin raw material. In this sense recycled materials are secondary raw materials that may be used in the production cycle of the original products (such as metals and some engineered plastics) or in a different production cycle generally less important in terms of industrial added value.

2.1 Eco-design Concept

Eco-design is a set of new approaches in engineering design that helps designers and engineers to incorporate materials criteria such as recyclability from the very beginning of a product development. One of these approaches is DFR -Design for Recycling – that consists in providing an added value recycling condition to new products at the end of their life cycle. It is some times also referred to as Clean Design or Design for Environment –DFE- or Sustainable Design, which means that the term is not yet clearly defined. Nevertheless these practices are being widespread worldwide from packing to complex products such as vehicles. According to Tischner [2], for instance, sustainable design goes beyond technical aspects of eco-design integrating social and ethical aspects of the product‘s life cycle alongside environmental and economic considerations.

So eco-design has recently been enlarged to cope with recycling end of life product. In this sense eco-design is about to integrate environmental criteria on project and product development from cradle to grave. Which means to balance environmental requirements with the basic project requirements as cost, quality, security, delay, since the products are firstly conceived to be produced and to be efficiently used by theirs customers and secondly to be dismantling and recycled. But eco-design a product as complex as a car aiming to minimize its environmental impact over its whole life cycle is not an easy task although it is fundamental to encompass environmental legislation and standards such as the ELV Directive and ISO 14000.

In fact eco-design calls for eco-designing tools as Ernzer M., Oberender C. Birkhofer H have pointed out [3]. From the designing phase up to a product industrialization a number of methods helps to evaluate or calculate the environmental impacts of the different choices that have to be make during product development or adaptation – redesign –. The most used methods are LCA – Life Cycle Assessment- considered by ISO 14040 the most accurate one to can guide materials choice environmental oriented - and Eco-Indicator 99 that permits to estimate different materials impacts multiplying its weight or its energy consumption by a specific factor. Combinations or adaptations of these methods can be done according to the project main goals or the environmental corporate strategy adopted. So DFR, DFE, DFD – Design for Disassembly – are going to require different emphasis on materials content, energy consumption, gas emissions, effluents or scraps generation etc.

Concerning recycling car eco-design has to do with the very first recycling phases of end of life vehicle: preconditioning and dismantling. Preparing dismantling the first step is draining all fluids and removing any component containing hazardous substances and listed in appendix 1 of 2000/53 Directive: such as batteries and air bags, and catalytic converters and other elements containing mercury, copper or aluminum that could not be separated out in the shredder. Next step the reusable parts and those made of recyclable materials are removed including tyres, glass, bumpers, dashboard and fluid containers. These two steps are crucial to optimize car recycling technically and economically as well [4]. The task is complex since automobile is a multi-components product in which more than twenty thousand of different parts, made of a number of raw materials, are assembled by a wide spectrum of processes and techniques. And at the end of its life vehicles will represent a buck of multi-component materials that cannot directly be reconverted into new auto parts. So the complex interconnected materials cycles originating from recycled cars have to be optimized from a technological as well as an economic point of view [5]. This optimisation effort depends on what kind of support you can get from the design tools to integrate environmental criteria such as recyclability in materials selection and assembly processes from the very first stages for product development.

In the past, materials were selected from a “menu” where all available materials were listed. Materials substitution was done part by part, e.g. a plastic bumper replacing steel one. During the late eighties carmakers had largely implemented the simultaneous engineering approach, and took advantage in reducing the number of parts in a vehicle by integrating functions embodied in new parts. From now on they do all the project phase in parallel, rather than in sequence, and in partnership networks including materials suppliers, auto parts producers, electronic systems dealers, and, together, they have to rethink globally the conception of new cars balancing technical performance and environmental impacts, from the birth to the death of the new vehicle. The project specifications have to go from the assembly to the disassembly specifications to enhance the recyclability of the automobile as a whole [6].

The development of eco-tools has been required as a set of design instruments to translate environmental legislation into project language for better guiding materials selection. They include accurate tools such as internal guidelines, rules and standards, periodically reviewed, and dedicated software to get environmental criteria integrated in project data bases throughout the designing phases [7]. The development of these tools goes back as far as ten years ago since then simultaneous engineering tools such as computer-aided design –CAD- are being linked to recycling models and LCA information to cope with environmental legislations targets. Schaik and Reuter [5] state that "in order to optimise the resource cycle and maximize the recycling rate of future vehicles... fundamental knowledge of recycling processes, such as shredding, mechanical separation and metallurgy, and materials characteristic of recycling (intermediate) products, have to be combined with that of the design of the product (materials combination and intersection)." These authors propose a dynamic model that links CAD software and recycling models in car projects.

A good example of the development of eco-tools is provided by Renault in conducting its eco-design activities since 1999. Renault recycling strategy is supported by this cross-functional organization. A Recycling Service was placed at Materials Engineering Direction at Technocentre to participate at all projects development simultaneously. A cross-functional team translated the European Directive recommendations on car project language promoting a more eco-efficient and cost effective materials choice in order to facilitate the EVL disassembly for recycling and components recycling as well. A long-run partnership between Renault and their first tiers suppliers was also established to assure the economic viability of ELV and components recycling. They work in network sharing simultaneous engineering software and accessing web based data entry such as the one provided by IMDS (International Materials Data System) in which car manufactures compile data on vehicles composition [7].

Since 2004 the software called OPERA -Overseas Program for economic recycling analyses-, the state of art in terms of eco-design tools, is being use at Renault for materials selection. OPERA is a means of integrating different materials selection critera to car design, including materials recyclability, plastic compatibility, alternatives on jonings and other manufacture processes that can impact car disassembling and recycling phase, etc. This sofware also takes into considerantion external information on recycling such as technolgical and industrial capabilities to assure recycling cost effectiveness and also the existence of a market for recycled materials.[4] In the words of the former chief of Recycling Service at Renault Engineering Materials Direction Robert Lassartesses- *En fait l'OPERA aide à concentrer le démontage par exemple dans ce qui n'est pas cher à démonter. Il a été utilisé par exemple dans le projet du MODUS pour assurer les 95% de recyclabilité et mieux guider le choix entre les pièces plastiques celles que fallait garder comme démontables, ex : bouclier, passage de roues, grille avant etc... ou celles que ne le fallait pas tel que les tapis de revêtement intérieur, ou ceux du coffret." ... "En plus à l'extérieur de l'entreprise il y a les partenariats avec les fournisseurs, plasturgiste, sidérurgistes, Associations etc.* " (Entretien réalisé par Heloisa Medina avec Robert Lassartesses à la DIMAT Direction de l'Ingénierie des Matériaux, au Technocentre, le 22 février 2005). According to Lassartesses the key eco-tools for this purposes are the IDIS -International Dismantling Information System- and long run parternerships with suppliers and raw materials producers as well.

Although the ELV Directive has already affected the design of new vehicles, there are currently no legislative ELV measures on the design process itself [8]. In this sense concerning materials choice for eco- design the *Norme Renault Conception en Vue du Recyclage (00-10-060/ 2002)* gives technical guidelines to materials selection for recycling getting to new models higher index of recyclability and increasing usage of recycled and renewable materials as well. There is also a special regard to plastics recommending not only the type of material, but also the assembly joining process. The plastics selection is done according to a table of compatibility avoiding all incompatibility among different materials as component of the same part or related parts [4].

2.2. Eco-design and recycling practices in Brazil

Since the early nineties recycling are becoming a new and sound and competitive industrial activity in Brazil. The main secondary materials for reprocessing are aluminium, steel, glass, paper and plastics. These materials came from end of life products as well as from components and parts from manufactures suppliers of automotive sector and electric and electronic devices.

The automotive world companies were first established in Brazil in the 1930s with trucks, buses and cars assembled from imported parts, components and engines. After II World War the automotive sector settled the basis of an increasing vertical integration internally protected by trade barriers and regulations on import of vehicles and auto parts. After on the middle 1990s automotive industry in Brazil passed through a restructuring process at the production level as well as the industrial organization, including the search for a more environmental friendly profile under the influence of Rio 92 World Summit – the second United Nations Conference on Environment and Development realized in Rio de Janeiro. As a consequence Brazil has taken advantage of this global restructuring process towards a more flexible and a greener production organisation. In this context the new entrants car companies and the new plants, made by the companies already present in the country, built up their plants in phase with the state-of-art at organisational and technological innovations and with the best environmental practices as well. Nowadays, in 2006, almost all global vehicles manufactures (car, trucks and buses) have modern and clean plants in Brazil. Moreover Brazilian new plants such as Renault and Volkswagen-Audi in the state of Paraná, PSA - Peugeot-Citroen and Volkswagen Trucks in Rio de Janeiro, and Ford in Bahia are the cleanest industrial facilities of theirs companies in the world [7].

The Latin America R&D Centre of Industrial Complex Ford Northeast, located at Camaçari in Bahia, has been designing vehicles since 2002 under the most restricted substances management standards (RSMS), as part of the overall process of materials reporting and certification Ford program. Internal Ford practices are being strengthened to facilitate the up-front design of components free of restricted substances. At the same time, part manufactures must confirm design execution by complying with IMDS reporting requirements. The expectation for 2006 was that suppliers provide initial part submission early in the product development cycle and supplemental detail later, concurrent with final part approval [7]. Ford Camaçari industrial complex launched in 2002 the first eco-designed vehicle ever produced in Brazil named EcoSport, which incorporates the highest level of light materials such as aluminium, plastics and composites. It is the bestseller model of the company since then and its basic composition in terms of materials is showed at the Table 1.

Table 1 : Eco-Sport basic materials composition

Type of material	Weight participation
Ferrous Metals	69%
Plastics	12 %
Aluminium	7,3%
Fluids	2,1%
Copper	0,6 %
Others	7 %
Divers (mainly composites)	2 %

Source: Ford Company Department of Product Development at Camaçari Plant that was visited by Medina and Naveiro at October 2006.

But eco-design practices, such as DFR new vehicles and auto parts adopted by car companies in their countries, represents for Brazil at one time a threat and an opportunity. A threat in the sense that the new models are multimaterials and light-materials made which means more plastics and light metals alloys that were not developed in the country. An opportunity because these new materials were conceived to be recyclable and most of them are produced domestically, by newcomers suppliers such as Plastic Omnium (PO) and Peguform that, among others, are global full-service-suppliers of plastics parts and components for automotive industry, designing and manufacturing and single plastic components, systems and complete modules as well. They came to add new blends to the traditional thermoplastics production Brazilian sector that was already the most important of Latin America. From 1998 to 2003 Brazil doubled Polypropylene installed capacity and increased in 60 % the internal sales, exporting only 15% of its internal production. Nevertheless PO in France had already designed and produced bumpers from 35% of recycled polypropylene but in Brazil this proportion could not be as higher as 7%, which corresponds to the volume of industrial scrap recovered at the PO plant. This situation is due to the lack of quality of the recycled material, since for logistics and economic reasons it is recycled mixed to other materials from different origins [7].

3. CORPORATE STRATEGIES, ENVIRONMENTAL PERFORMANCE AND DFR IN BRAZIL

As part of corporate strategies DFE and DFR practices have been globally defined and locally applied. However, local conditions are supposed to have a great impact on recycling chain and these practices are not able to assure the best environmental performance worldwide. The core point of our case study in Brazil is that eco-designed products produced at industrial plants located in developing countries are improving environmental performance at company level but also claims for incorporate technical, economic and regulatory conditions on the design phase.

In the 90s following the new competitive basis adopted by the industrialized countries, Brazilian economy was open to the international market facilitating easier the importation of products and components, including the automotive ones, for speed its modernization process. New automotive manufactures and suppliers – came to Brazil intending to profit from the benefits of the local market, which has been increasing with the *Mercosul*, which guarantees a wider participation in the world market. Multinational companies of the automotive sector took advantage of the fact of having plants in several countries and even in several continents to produce their products where it would be more competitive in economic terms. Thus, one of the determinants for lowering the price of vehicles, and the consequent increase of internal competitiveness (inside the group plants or divisions) and external competitiveness (in relation to other companies) is the nationalization of parts, mainly in countries, which present a wide internal market and the leadership at regional level such as Brazil and *Mercosul*. Besides in Brazilian case the exchange rate of national currency has reached a good stability

In such a context starts a wide process of auto parts nationalization, which involves laws, not only the Brazilian ones, but also those of the world, as cars produced in a certain plant must be appropriate to be exported to other countries. Thus, cars produced in Brazil by European multinational companies also comply with the European legislation on End of Life Vehicles and Recycling, including the eco-design. This, for example, has been making the companies in the automotive sector adopt locally the same environmental strategy defined in their countries of origin. However, there is not yet in Brazil an industrial policy that promotes the technical, logistic organization, and especially the fiscal and tributary incentives to take advantage of this potential. As result there is a loss in technological, economic and even environmental terms concerning the quality of automotive materials recycling. An example of this loss is the destruction of obsolete spare parts and this is what we present here based on the preliminaries results of a study case still in course.

3.1 A case study on the automotive sector in the state of Rio de Janeiro

The company studied will be called here KARITAS so as to protect its identity. KARITAS plant in Rio de Janeiro State has the capacity to produce 400 vehicles per day and has 2300 employees distributed into the two main activities of the plant: administration and production that is organized in three phases: body-in-white, painting and final assembling line. Three models of cars are produced and each one of them has several versions. Thus, the number of different references of parts used in this plant is of about six thousand -6.000-. In the case of model one, 70% of its parts come from suppliers from Brazil and Argentina (local suppliers) and the rest of the parts come from Europe. In the case of models two and three, only 50% and 60% of their parts, respectively, are from local suppliers.

Daily there are a great quantity of waste and residues from the industrial activity. Among them can be mentioned organic residues (mainly from the company canteen), residue of the dying process (dye dregs), packaging of automotive parts, and automotive parts themselves (rejected by quality control or undamaged inside the plant) etc. Each kind of residue has a different treatment and final disposal. In the case of the packaging, for example, the process is already fairly profitable for the company. As the product is easily identifiable and contains few different materials, its selection becomes easier, and besides, the market seems to be more familiarized with it. Therefore, with a less contaminated product, or better products with fewer different materials, there could be also a better acceptance by the market. The selling prices are more representative. In the case polyethylene plastic it can reach US$ 330 per ton.

The last type of residues is the one we are going to focus and is formed by all types of automobile parts discarded throughout the assembling phases.

3.1.1 Discarding automotive parts

Nowadays the company KARITAS presents two possible causes for discarding automotive parts: rejected parts or end of series components (ESC).

The rejected parts are those that, because of quality problems, cannot be mounted in the vehicles. It must be noticed that the majority of parts coming from local suppliers are returned to them to be replaced. In this case they do not become waste. So only a few parts whose problem was caused by transportation or utilization inside of the plant are rejected as residues. Thus, the majority of what is rejected and that is going to be considered a waste are imported parts and so not economic viable to be return to suppliers. For technical reasons only some of these parts are sent back to suppliers for quality tests and improvements.

The second category of discarded parts is the ESC considered as obsolete parts. The parts can become obsolete either because they have been replaced by a new model or a new generation one, or because the version or model of the vehicle to which they belong has been extinct. So, we can summarize by saying that those parts, for some reason, will not be used again in the new vehicles produced.

In fact the car makers have been forced to deal with an enormous quantity of obsolete parts to comply, not only with technical and environmental requirements and with the taste of a consumer's market eager for novelties, but also with the constant problems of stocking management and preview of stock. Besides the growing decrease in the life cycle of vehicle models are stimulated by not only technological evolution of materials and processes but also by new forms and approaches of design such as simultaneous engineering, DFE and DFR methods.

The management of the ESC starts at the PLS (Production Life Series) which provides the IO (Industrialization Order) which has the date in which the part will be replaced or stop being used (utilization date) Usually these IOs are issued for months before the utilization date so as to give time for them to be used.

Monthly the production planning control (PPC) deals with this information, planning to reach the date of the utilization to get zero stock. Often this is not possible, either because the quantity of parts in the assembling line is not the same as what is in stock, or because the quantity of parts is very large. Example: 2 parts mounted one on the right side and the other on the left side, if the quantity of left side parts is not the same as the quantity of right side parts, the one of which there is a larger quantity will not be eliminated from the stock. In the case of parts to be replaced, is easier to work with zero stock targets. But, when the part is supposed to be excluded, the process is somewhat more complicated. When the utilization date arrives, if there are still parts on the assembly line they are re-integrated in the stock. In the case of the parts that have not been used there are three attempts before destruction.

1) Try to sell them to group – at international level-.
2) Check if the parts are used in Argentina, checking the possibility of sending them there.
3) Contact the PLS (production life series) to check the possibility of opening a by-pass, i.e. using the end-of-series part temporarily.

Exhausted all these possibilities, the remaining parts are put on the list for destruction and Operational logistics Control will send them to an ESC stock, where they will wait for the day of the destruction. However, this list is first sent to the accounting sector, which will calculate the taxes and will start a process at the Brazilian Ministry of Economy Fiscal Agency *Receita Federal*. The day of destruction will be determined by the total volume that should be as high as around three hundred thousand components and a federal fiscal agent of *Receita Federal* is supposed to be present to approve and testify the destruction. At November 2006, the day of destruction we were present at there were about 350.000 ESC. Considering that one vehicle average number of auto parts is around twenty thousands (20.000) ESC represents almost 18 vehicles.

3.1.2 Some Legal and Accounting Aspects

According to the Brazilian legislation the companies pay taxes when they buy parts. Therefore the price paid for the part is composed by the price of the part plus taxes (ex.: 8000 – (price of the part) + 2000 (taxes) = 10000).

When the produced vehicle is sold, the client also pays for the value of the vehicle plus taxes (ex. 16000 (price of the vehicle) + 4000 (taxes) = 20000) However, as the taxes on the parts have already been charged on the occasion of their acquisition, this sum is credited to the industry (ex.: 4000 (tax on the selling of the vehicle – 2000 in taxes already paid in the acquisition of the parts = 2000 (Debit balance equivalent to the amount to be paid). When there are lost parts that will not be part of a vehicle to be sold, the process described above will not be completed (in the example, the company will have spent 10000 with the acquisition of the parts that will be thrown away.)

The destruction is done so as to minimize the impact of final disposal of useless parts. On the day of the destruction, an Federal Inspector follows the whole process to be sure that those parts are really destroyed (i.e., that they are not being sold as auto parts) and, as consequence, there will be the exemption of already taxes already paid for. In this example the company would only lose 8000, in case of commercialization of these components.

In the case of industrial wastes and residues the Brazilian legislation foresees a limit of production loss acceptable for each industry. As automobile industry has no transformation, only assembly, line this limit is low. Therefore, when the losses surpass this limit, taxes must be paid.

3.1.3 The destruction of End of Series Components

On the day of the destruction, the parts that are on the list are taken from the FDS stock (Figure 1) and are taken to the destruction place. The operators take the parts off from their external packaging – the internal packaging, such as individual plastic bags, is maintained – and they throw the parts on the ground (Figure 2). The roll to compress goes over the parts so as disfigure them taking away their characteristics (Figure 3) and then a kind of the carrying shovel takes them to the container of a recycling company. It is important to notice that there is no previous materials separation. The scrap is sold as mixed scrap, with very low aggregate value around US$ 10.00 dollars per ton. The materials separation has to be made at the recycling company facilities in order to permit the recovery secondary materials to be reused in industrial processes. Nevertheless the low quality of the recycling processes of this bulk of materials does not allow it to be reutilized for automotive uses. At least not at the same function they have had at their first life.

Figure 1: End of Life Components Stock.

Figure 2: Preparing for destruction

Figure 3: End of Life Components Destruction

4 SOME CONCLUDING REMARKS

DFR is a new concept of the design activity largely used in Europe due to Directive 053/2000 on End of life vehicle ELV and Recycling that incorporates materials recyclability from the very beginning of the product creation. So complex products like automobiles are from now on designed to be assembled and disassembled and made as much as possible of recyclable and recycled materials. As part of the new corporate environmental strategies, innovation in car projects incorporating environmental issues, and developing new tools for eco-design and materials choice are playing an important role in the environmental performance of car companies in Brazil as well. Nevertheless the organization of a vehicles recycling sector in Brazil is just beginning and is supposed to involve as many participants as possible to close the loop of vehicles production and consumption from automotive materials production to vehicles dismantling and recycling to recovery and reutilize them as secondary raw materials.

So even though environmental requirements for product design have been introduced during the last decade at various levels of intensity bay many car companies around the world, there is still a lack of suitable methodologies to deal with economic aspects at regional level that slows down the implementation of sustainable scheme of ELV and components recycling. Consequently, the current best practices diffusion is not easy and in particular in the less developed regions.

Nowadays regulatory framework is pushing new design methods and practices for environmental innovations, especially in Europe. New design and engineering tools allows continuous innovations on car industry that are speeding the launching of new models as fast as every three or two years. Besides the redesign of the ongoing models are getting them improvements to cope with environmental legislations and quality standards. This trend is generating a great volume of end of series components (ESC) which are difficult and costly to manage, and which requires logistics organization for environmental adequate disposal or recycling. Besides these new models are multi-materials and light-materials made which means more plastics composites and light metal alloys. And these have been environmentally conceived to be 100% recyclable and new suppliers that came after the new car manufactures since the middle nineties produce most of them domestically.

But even though developing countries like Brazil are fostering recycling activities trying to encompassing ELV Directive 2000/53/EC as indicate by the preliminary results of our study the complete reverse logistic for the organisation of car recycling sector is not an ease task for two main reasons. Firstly because on one hand, the automotive sector in Brazil comprises big multinational companies -around 23-, and on the other hand the recycling sector is locally based on small and medium enterprises. So the organization of recycling activities into technical and econmic competitive basis is a complex task from the logistic point of view. Secondly because there tributary and accounting aspects involved and there is also a lack of environmental legislation concerning vehicles recycling. Nevertheless we also belive that the success of this end of life vehicles and components recycling sector depends on Brazilian automotive engineers' capacity to participate at product design, especially regarding DFE, DFR, DFA and Dissassembly methods, to encompasse the international trends.

In fact the first results of our case study, conducted at Rio de Janeiro automotive industry, verified that the diffusion of eco-design practices is participating at the european manufactures companies stablished in Brazil and and improving their envrionmental performance. The current data presented give us a good idea of the problems involved on ESC management and destruction and how the present system claims for improvements in order to get the best advantages from the eco-design parts at the recycling local chain. In fact the destruction as it is done up to now represents a environmental improvement compared to the former system of discarding, and concerns eco-designed parts free that are recyclable and free from toxic substances. At the next step this case study will determine which are these advantages supposed to be and how to get them by means of a disassembling and sorting tests made for a selected sample of ESC. Considering the destruction of 350 thousands ESC and the average of 20 thousands auto parts per vehicle, the present system represents a waste of 18 vehicles, or 5 % of the production capacity of the studied plant.

AUTHORS' CONTACTS

Heloisa Medina **hmedina@cetem.gov.br**
Ricardo Naveiro **rnaveiro@pep.ufrj.br**
Ana Julieta Malafaia **ana_malafaia@hotmail.com**

ACKNOWLEDGMENTS

Our best acknowledgments to CNPq -National Council for Science and Tecnology Development- attached to Brazilian Ministry of Science and Technology , for the two years 2006-2008 financial support to our research program Product Design for Recycling -PROCICLE- Projeto de Produto Orientado para Reciclagem.

REFERENCES

1. Directive 2000/53/EC of the European Parliament and of the Council, on end-of life vehicles, available at http://europa.eu.int/comm/environment/waste/elv_index.htm

2. Tischner, U. 2005 “Sustainable Product Design”, presented at 3° International Congress of Design Research, 12 to 15 October, Rio de Janeiro, Brasil.

3. Ernzer M., Oberender C. Birkhofer H., “Methods to support Eco-design in the Product Development Process”, in 3° International Congress of Design Research, 12-15 October (2005) Rio de Janeiro, Brazil.

4. Medina H. V., 2006, "Eco-design for Materials Selection in Automobile Industry”, Proceedings of 13th LCE /CIRP 2006 Vol 2, pp299-304.

5. Schaik A. van and Reuter M. A., 2004, “ The Optimization of End-of-Life Vehicle Recycling in the European Union”, JOM, August, pp39-47.

6. Medina, H. V. de and Naveiro, R. M. 2001, Managing the Integration between Design, Research and Production in the Automobile Industry, Proceedings of the 13th ICED Vol. 02, pp 449-456.

7. Medina, H. V. de and Naveiro, R. M., 2007, “Eco-design practices in Europe fostering automotive vehicles recyclability in Brazil”, sent to IJATM International Journal of Automotive Technology and Management editorial board in January 2007.

8. Edwards C., Bhamra T. and Rahimifard S., 2006, “A Design Framework for End-of-Life Vehicle Recovery”, Proceedings of 13th LCE / CIRP 2006, pp365-370.

9. Renault Norme 00-10-060/2002, "Ecoconception en vue du Recyclage", Nornalisation Renault Automobiles, Service 65810, Section Normes et Cahiers de Charges, 23 p.